Ocean Dynamics and Acoustic Variability in East China Sea

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LONG TERM GOALS

Study the effects of ocean dynamics on acoustic propagation and underwater communication in the region of East China Sea (ECS).

OBJECTIVE

Conduct a joint shallow water acoustic experiment with KIOST (Korea Institute of Ocean Science and Technology) and KRISO (Korea Research Institute of Ship and Ocean Engineering) to study the coupling of oceanography, acoustics, and underwater communications in the ECS. Carry out measurements of the space and time environmental and channel impulse response characteristics along with satellite imagery for internal wave activities in the experimental area.

APPROACH

The ECS and surrounding area is an extremely complex region from the perspective of oceanography, hydrography, and bathymetry. In turn, the internal wave activity within this region is also extremely complex [1]. Within the ECS, there are several mechanisms for generating internal waves including: tidal forcing, forcing by the Kuroshio, Tsushima, and Yellow Sea Circular currents, upwelling induced by the intrusion of the Kuroshio across the continental shelf (mostly in the southern region near Taiwan), and freshwater discharged from Yangtze River, as illustrated in Fig. 1(a). Bathymetry is also an important factor in internal wave generation and propagation.

While the impact of acoustic field variability associated with internal waves propagating from deep to shallow water (e.g., South China Sea) has been studied extensively, the impact of internal waves in shallow water and broad shelves (e.g., Yellow Sea and ECS) and their interactions still is poorly understood.

During August of 2008, the ONR-sponsored Transverse Acoustic Variability EXperiment (TAVEX) was carried out in shallow water (70-80 m) within the northern ECS denoted by a red box in Fig. 1(a), southwest of Jeju Island, South Korea, with major emphasis on the effects of internal waves on signal coherence along a bottom-mounted horizontal line array [1,3]. Separately, the Asian Seas International Acoustics EXperiment (ASIAEX) involving several countries was conducted in the spring of 2001 to understand properties of the shallow-water boundaries governing propagation and reverberation in the ECS along with geo-acoustic properties of the seabed [2].

On the Korean side, KIOST/KRISO scientists have been keen on a collaborative research effort with the US to explore and better understand the coupling of oceanography, acoustics, and underwater communications in this very dynamic region of the Western Pacific. Motivated by the common interest in the region, SIO and KIOST/KRISO have agreed to collaborate on a joint research program involving a field experiment in the area of interest as a first step forward. For experimental planning and discussing potential ideas, the pre-cruise workshop was held at Jeju University, Jeju, August 27-29, 2014, with over 30 papers presented.

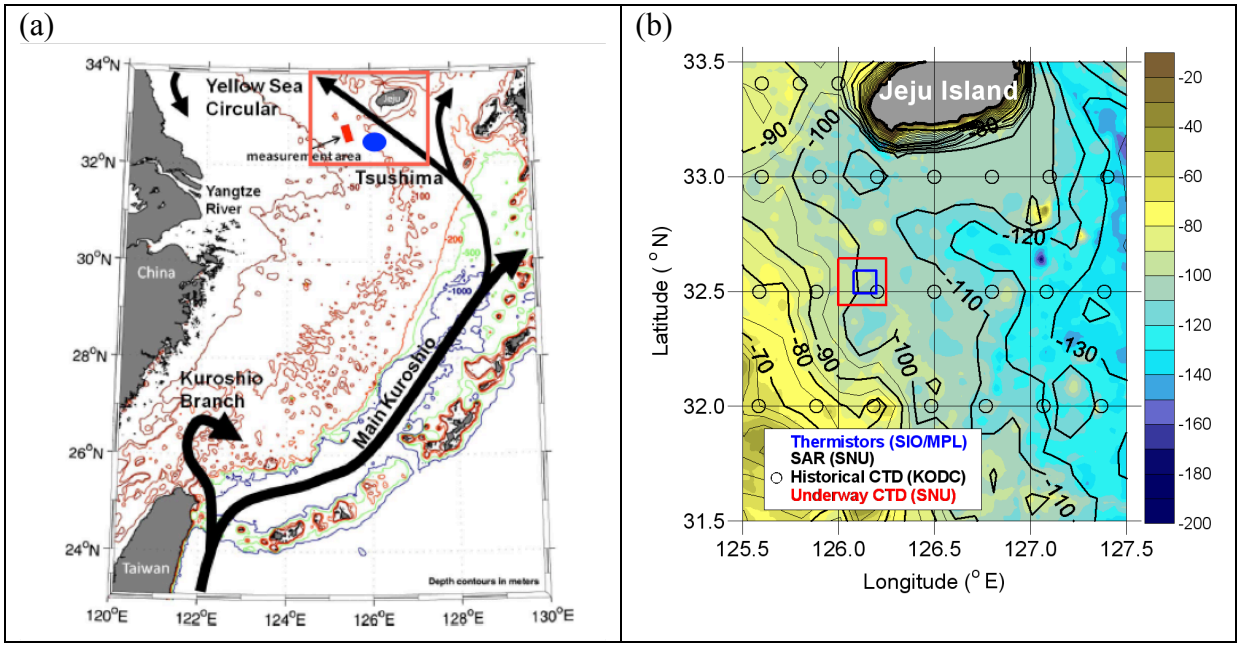


Figure 1. East China Sea (ECS) with main Kuroshio Current and its branches including Tsushima Current, along with Yellow Sea Circular Current. The SAVEX15 operational area is denoted by a solid circle (blue), while the TAVEX2008 is marked by a solid rectangular box (red). (b) General experimental area in the northern East China Sea (ECS), southwest of Jeju Island, Korea. The SAVEX15 operational area is north of 32˚30'N and east of 126˚5'W. Depth contours are in meters.

WORK COMPLETED

The Shallow-water Acoustic Variability EXperiment 2015 (SAVEX15) was conducted in shallow water (~100 m deep) in the Northern East China Sea (ECS), ~100 km southwest of Jeju Island, South Korea, over the period 14-28 May, 2015 (see Figs. 1 and 2). The R/V Onnuri operated by the KIOST (Korea Institute of Ocean Science and Technology) was used to deploy/recover all equipment.

The goal of SAVEX15 was to obtain acoustic and environmental data appropriate for studying the coupling of oceanography, acoustics, and underwater communications in the ECS. Of specific interest is to collect acoustic and environmental data which will relate the impact of a fluctuating oceanographic environment (e.g., nonlinear internal waves) and source/receiver motion to fluctuations in the waveguide acoustic impulse response between multiple sources and receivers and ultimately to the design and performance characterization of underwater acoustic digital data communication systems in shallow water. The focus was on fluctuations over scales of a few seconds to a few tens of seconds that directly affect the reception of a data packet and packet-to-packet variability, as well as on long-term (2-3 days) performance variations.

One 8-element vertical source/receive array (SRA) and two 16-element receiving arrays (VLA1 and VLA2) were deployed (see Fig. 2) as well as a towed source and a low-frequency KIOST SeaNos source. A limited number of environmental instruments also were deployed: CTD, underway CTD, waverider buoy, thermistor strings attached to each of the two VLAs, mutlibeam echo sounder (MBES) and single beam echo sounder.

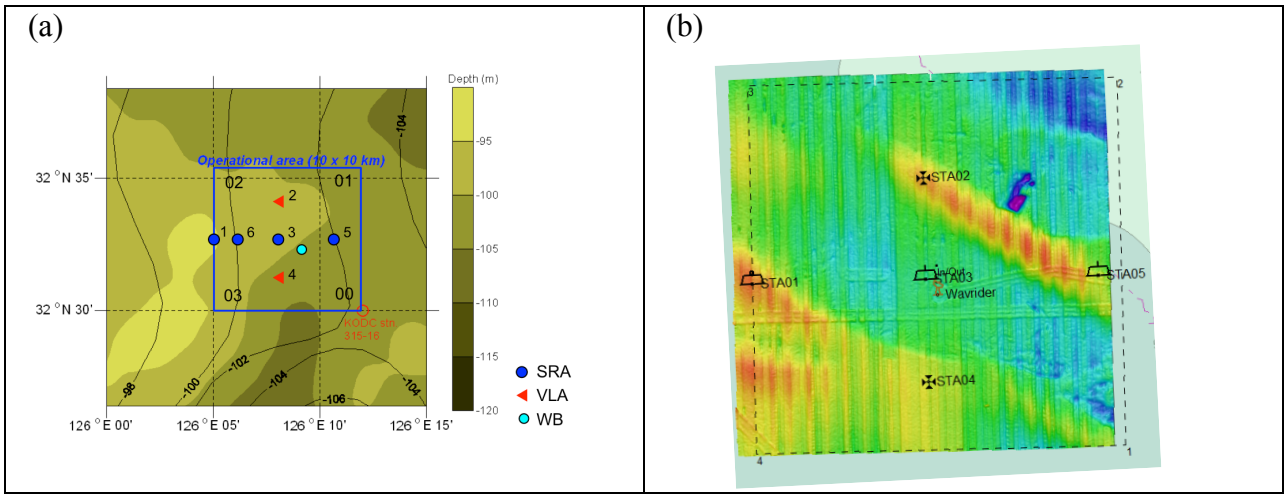


Figure 2. (a) Mooring deployment positions in latitude and longitude. Circles are SRA locations and triangles are VLA mooring locations along with the waverider buoy (WB). The overall SAVEX15 operational area (10 x 10 km) is enclosed by the blue solid line. Depth contours are in meters. (b) Bottom bathymetry and depth around the experimental area using MBES (multibeam echo sounder) system. Note that there are several sand dunes in the area. VLA1 (Station 2) is moored above a sand dune.

Examples of Experimental Results

Environmental Measurements

Temperature loggers were deployed on the two VLAs (VLA1 and VLA2). In addition, CTDs and underway CTDs were taken as often as possible during the experiment. Examples of the CTD-derived sound speed structure at various locations and times during SAVEX15 are shown in Fig. 3, indicating a SOFAR channel formed even in this shallow region likely due to the intrusion of warmer, saltier Kuroshio (Tsushima) Current into the ECS.

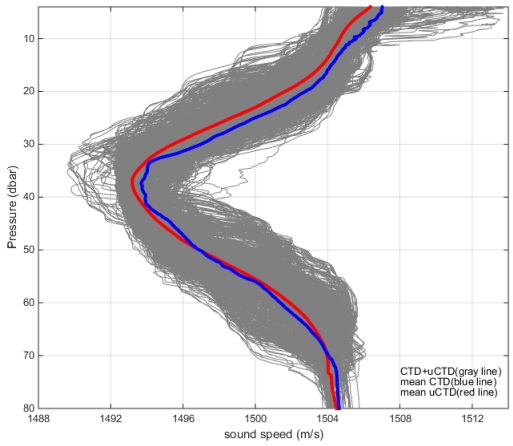


Figure 3. Sound speed profiles (m/s) collected using the standard SBE 9-11plus CTD (gray, 22 profiles in total) and the Underway CTD (gray, 1,024 profiles in total) during the SAVEX15, May 15-25, 2015. Mean profiles also are shown in blue (standard CTD) and red (Underway CTD).

Ambient Noise and Snapping Shrimp Sound

An example of ambient noise spectrum is shown in Fig. 4(a). Broadband (5-40 kHz) snapping shrimp noise was ubiquitous in the experimental area. Strong snapping shrimp sound can be isolated to localize the source using the Bellhop ray model as shown in Fig. 4(b) (i.e., 79-m away from the array (VLA2) at the bottom (100-m)).

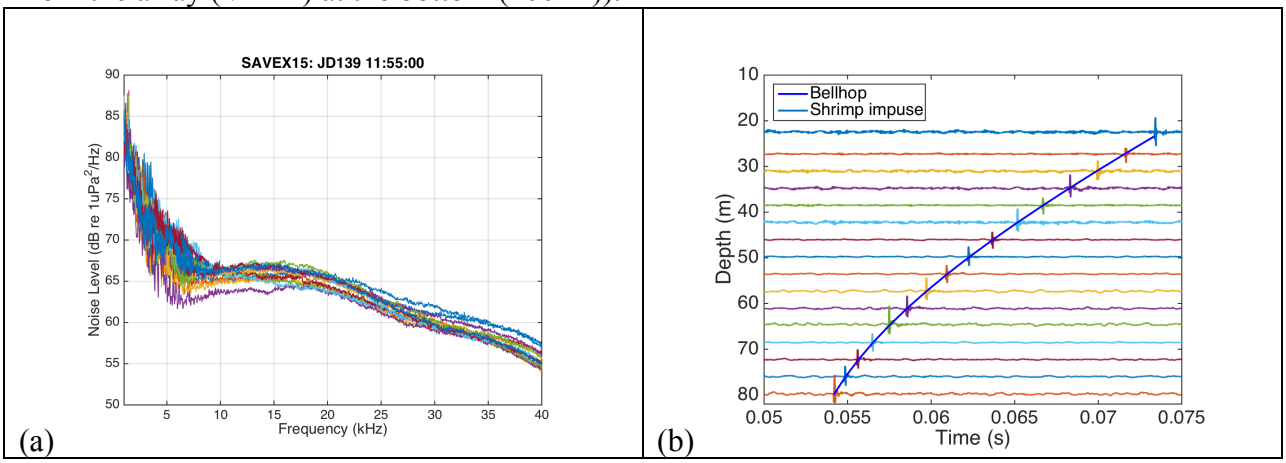
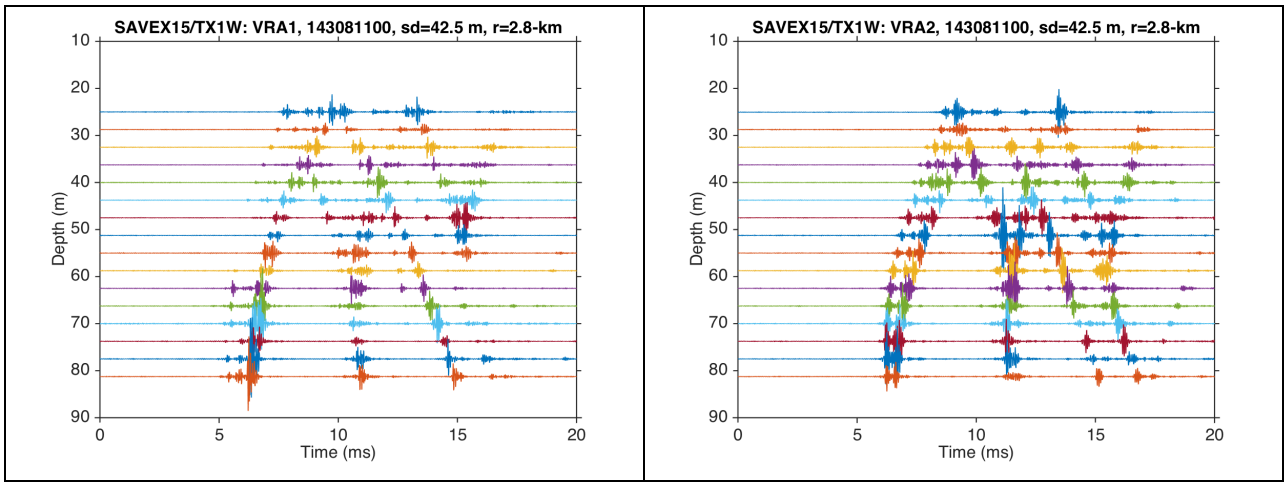


Figure 4. (a) An example of ambient noise spectrum (1-min averaging). (b) Snapping shrimp impulsive noise captured by the VLA2. A point source located 79-m away from the VLA2 at the bottom (100-m) matches the arrival structure.

Channel Impulse Response and Acoustic Communications

The acoustic data collected during SAVEX15 include transmissions from the source arrays (SRA) and towed source tracks. Examples of channel impulse responses captured by VLAs from a moored SRA (Station 3) are shown below: VLA1 (left) and VLA2 (right).



IMPACT/APPLICATIONS

The joint experiment in the northern East China Sea turned out to be successful and our Korean counterparts were very pleased to collect such a good quality of data. In the future, we see an opportunity to grow a collaborative program with South Korea utilizing their substantial facilities and assets, while their benefit is interaction with our ocean acoustics group and expertise.

References

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[3] S. Kim, Y.G. Kim, Y.N. Na, and A. Turgut, "Geo-acoustic inversion using ship radiated noise in the TAVEX," TAVEX workshop, 2009.

[4] H. C. Song et al., SAVEX15 Cruise Report, Marine Physical Laboratory/Scripps Institution of Oceanography, La Jolla, CA, 2015.